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PRESSURE HISTORY OF A GAS PIPELINE

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REPORT MTL 90-3(TR)

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ABSTRACT

A pressure sequence representing one year of operation of a gas pipeline is presented. The sequence is to be used in tests to determine realistic stress corrosion crack (SCC) growth rates. The sequence has been derived by counting cycles on discharge pressure charts from a compressor station on a pipeline which experienced several SCC failures.

LABORATOIRES DE LA TECHNOLOGIE DES MÉTAUX
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ÉVOLUTION DES PRESSIONS DANS UN GAZODUC

par

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RÉSUMÉ

Une séquence de pressions correspondant à une année d'utilisation d'un gazoduc est présentée. La séquence doit être utilisée dans des essais visant à déterminer des taux réalistes de croissance de fissures par corrosion sous contrainte (FCC). Elle a été établie par comptage des cycles dans des diagrammes de pression de sortie d'un poste de compression dans un gazoduc ayant subi plusieurs ruptures par FCC.

INTRODUCTION

Extensive stress corrosion cracking (SCC) has been found during recent years in Canadian gas pipelines. Beginning in 1985, SCC resulted in several operational and hydrotest failures in lines operated by TransCanada PipeLines (TCPL).

Examination of failures and extensive field research revealed that SCC in Canadian pipelines differs from the known "classical" SCC in that the electrolytes found above SC cracks are dilute and have lower pH (near neutral) compared with classical electrolytes. Rates of crack growth in the dilute electrolytes, important for determination of residual life of a cracked pipeline, are not yet known.

Relevant SCC growth rates are to be measured within a joint research project with CANMET, the University of Waterloo, NOVA Corp., and TCPL. The crack tip strain rate generated (among other factors) by stresses from pressure fluctuations in a pipeline is one of the most important parameters controlling the crack growth rate (1,2). Since representative pressure histories of gas pipelines are not available, cycle counting was performed on the TCPL pipeline which experienced several service failures. The method of cycle counting, and the results - a one-year pressure sequence to be used in SC crack growth rate tests - are described in this report.

PRESSURE HISTORY

The TCPL line 100-2, which failed by SCC three times in 1985-86, was selected for cycle counting in order to obtain a representative pressure sequence. The pipeline, 914 mm diameter, 9.14 mm wall thickness, is made of 448 (X65) Grade steel. The maximum operational pressure (MOP) is 6950 kPa.

Cycles were counted on twelve succesive discharge pressure charts from compressor station No. 92. Each chart covered about thirty days of operation, combined, approximately one year immediately preceeding one of the SCC failures. The failure occurred on 20 August 1985, 12.3 km downstream from the station.

The ordered overall range counting method (3) was used in cycle counting, done visually on the pressure charts. The method, used previously in development of pressure history for a crude oil pipeline (4), makes it possible to screen out small amplitude cycles with negligible contribution to fatigue or SCC damage. The screening makes the sequence manageable by eliminating the numerous small cycles. The overall pressure range, from zero to maximum operating pressure (MOP), is applied very rarely during gas pipeline operation, and has not been found in the available charts. Because SCC can be sensitive to very small load fluctuations, a very low screening level was adopted in cycle counting. Only ranges smaller than 100 kPa (1.4% of the overall range) were screened out.

A one-year pressure history, from August 15 1984 to August 16 1985, containing 621 reversals (peaks and valleys) or 310 cycles is presented in Fig. 1. Table 1 gives the history in digital form. The mean pressure is 6612.1 kPa. The sequence is broad band in nature with an irregularity factor (number of positive mean crossings/number of peaks) i = 0.71. The distribution of pressure ranges (peaks minus valleys) is shown in Fig. 2a, and distributions of peaks and valleys in Fig. 2b. As can be seen the most common range is 150 kPa, the most common peak is 6850 kPa. The MOP was slightly exceeded three times during the year.

The period of a cycle varied widely, from several minutes to about one week. The mean period is 28.3 h giving a mean frequency of 0.00001 Hz.

Pressure fluctuations were less frequent and less severe during the winter period, January to May, than during the rest of the year. Allegedly, operating the pipeline at full capacity facilitated pressure control. During the winter period, the average number of cycles per month was 15 while during the rest of the year it was 32 cycles per month. In the pressure sequence, Fig. 1, the winter period, with a visibly smoother pressure spectrum, extends from 330 to 510 reversals.

To verify that the present pressure sequence is representative of longer term pipeline operation, additional cycle counting was performed on two one-month charts, one each from winter and summer, from a period one year earlier. Comparison of pressure fluctuations in terms of range distributions are shown in Fig. 3a and 3b. The summer period, represented by July 1985, is compared with July 1984 in Fig. 3a. The winter period, represented by January 1985, is compared with January one year earlier in Fig. 3b. As can be seen, monthly distributions of pressure ranges for both summer and winter periods are similar in both years. Monthly cycle counts in 1985 were slightly higher then in 1984: in summer 30 cycles compared to 27, in winter 15 compared to 10. This suggests that pressure fluctuation in 1984/85, just before the SCC failure, might have been slightly more severe than in earlier years.

The pressure charts contained discharge and suction pressures. Only discharge pressure cycles were counted. The suction pressures were 1000 to 2000 kPa lower than the discharge pressures. Visual observation during cycle counting indicated that the number of cycles in suction pressure, and intensity of pressure fluctuations, were about equal to those in discharge pressure. This indicates that the whole length of the pipeline experiences about the same spectrum with only mean load decreasing with distance from a compressor station.

DISCUSSION AND CONCLUSIONS

The pressure sequence, derived from cycle counting over a one-year period, is believed to be representative of conditions leading to stress corrosion crack growth in gas pipelines for the following reasons:

(i) The cycles were counted over a one-year period just preceding an SCC failure, on discharge pressure charts from a compressor station 12.3 km upstream from the failure site. Two additional SCC failures occurred elsewhere on the same line within six months of this failure.

(ii) Comparison of discharge and suction pressure fluctuation suggests that the whole line experiences about the same pressure spectrum.

(iii) Pressure cycle counts from two months during the preceding year were not significantly different.

The one-year sequence contains 310 cycles with rather small ranges. The maximum range is close to 20% of the MOP, and the majority of ranges are close to 2% of MOP. The average frequency is one cycle per 28 h (0.00001 Hz), somewhat lower than one to two cycles per day believed to be typical for gas pipelines.

REFERENCES

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Table 1. Pressure sequence

6950	6300	6850	5950	6750	6650	6800	6650	6800	6500	6800	6350
6900	6400	6550	5050	6650	6250	6900	6200	6700	6550	6700	6450
6850	6250	6650	6150	6800	6150	6750	6500	6900	6750	6850	6750
6900	6350	6750	6500	6800	6600	6900	6400	6700	6350	6850	6600
6850	6050	6750	6600	6900	6600	6850	6700	6900	6000	6900	6750
6850	6750	6850	6700	6900	6500	6850	6750	6900	6750	6900	6350
6700	6500	6900	6400	6700	6400	6800	6400	6800	6350	6850	6700
6850	6300	6750	6300	6850	6700	6850	6300	6850	6750	6850	6700
6800	6650	6850	6600	6800	6400	6600	5850	6100	5650	6500	6350
6850	6700	6850	6600	6700	6450	6900	6500	6800	6650	6850	6750
6850	6650	6850	6600	6850	6650	6900	6250	6900	6700	6850	6700
6850	6550	6850	6750	6850	6750	6850	6750	6900	6800	6900	6700
6850	6750	6850	6750	6900	6650	6750	6600	6750	6250	6550	6400
6800	6300	6900	6450	6900	6650	6900	6500	6900	6800	6900	6700
6850	6600	6900	6600	6850	6750	6900	6450	6550	6450	6700	6550
6850	6600	6750	6500	6850	6650	6900	6650	6850	6450	6800	6550
6800	6550	6850	6700	6850	6100	6750	6150	6350	6150	6850	6550
6850	6750	6850	6250	6850	6500	6750	6500	6750	5400	6550	6400
6850	6650	6850	6650	6850	6750	6850	6750	6850	6750	6850	6550
6900	6800	6900	5800	6850	6700	6800	6300	6850	6300	6850	6600
6800	6150	6900	6650	6850	6450	6850	6500	6850	6600	6850	6700
6800	6350	6800	6450	6900	6200	6550	6200	6300	6100	6200	5900
6100	5500	6250	6150	6300	6200	6350	6250	6850	6450	6550	6400
6850	6400	6500	5400	6850	6750	6850	6700	6900	6600	6850	6500
6900	6200	6850	6200	6800	6600	6800	6600	6850	6600	6850	6000
6900	5950	6150	5800	6100	5850	6100	5800	6100	5800	6100	5700
6900	6800	6850	6250	6850	6400	6750	6600	6850	6750	6900	6600
6850	6650	6850	6650	6850	6500	6850	6750	6850	6700	7000	6750
6900	6700	6900	6700	6850	6400	6850	6300	6900	6650	6800	6700
6850	6650	6750	6500	6600	6300	6850	6100	6850	6300	6750	6650
6850	6600	6850	6700	6850	6500	6900	6650	6800	6700	6900	6450
6850	6500	6900	6700	6850	6500	6800	6400	6800	6500	6800	6500
6800	6600	6850	6400	6800	6500	6800	6700	6750	6050	6850	6750
6850	6700	6850	6450	6850	6700	6850	6400	6550	6400	6600	6500
6800	6250	6550	6300	6700	6400	6750	6450	6550	6300	6600	6400
6650	6550	6750	6050	6750	6400	6800	6350	6700	6550	6700	6200
6550	6350	6450	6300	6800	6500	6800	6700	5800	6700	6800	6500
6750	6600	6850	6200	6850	6500	6800	6700	6850	6650	6850	6550
6950	6550	6700	6550	6800	6550	6750	6550	6800	6650	6750	6350
6850	6350	6700	6450	6700	6550	6800	6500	6850	6650	6800	6650
6850	6300	6800	6150	6650	6200	7050	6550	6800	6500	6900	6650
7150	6700	6800	6500	6750	6600	6800	6400	6750	6400	6750	6300
6800	6450	6850	6700	6850	6700	6850	6700	6900	6600	6900	6550
6700	6350	6800	6150	6650	6500	6700	6400	6550	6350	6850	5900
6600	6350	6600	6350	6700	6350	6700	6450	6700	6400	6550	6200
6750	6150	6800	6250	6600	6350	6500	6400	6900	6350	6850	6650
6800	6600	6850	6650	6900	6250	6900	6700	6900	6250	6900	6400
6650	6250	6900	6050	6850	5900	6600	6400	6750	6200	6850	6700
6900	6300	6700	6050	6800	5800	6900	6800	6900	6350	6800	6250
6800	6350	6800	6200	6900	6750	6900	6700	6800	6200	6450	6250
6750	6250	6900	6700	6900	6500	6650	6500	6700	6500	6700	6500
6900	6500	6800	6600	6800	6200	6850	6700	6950			

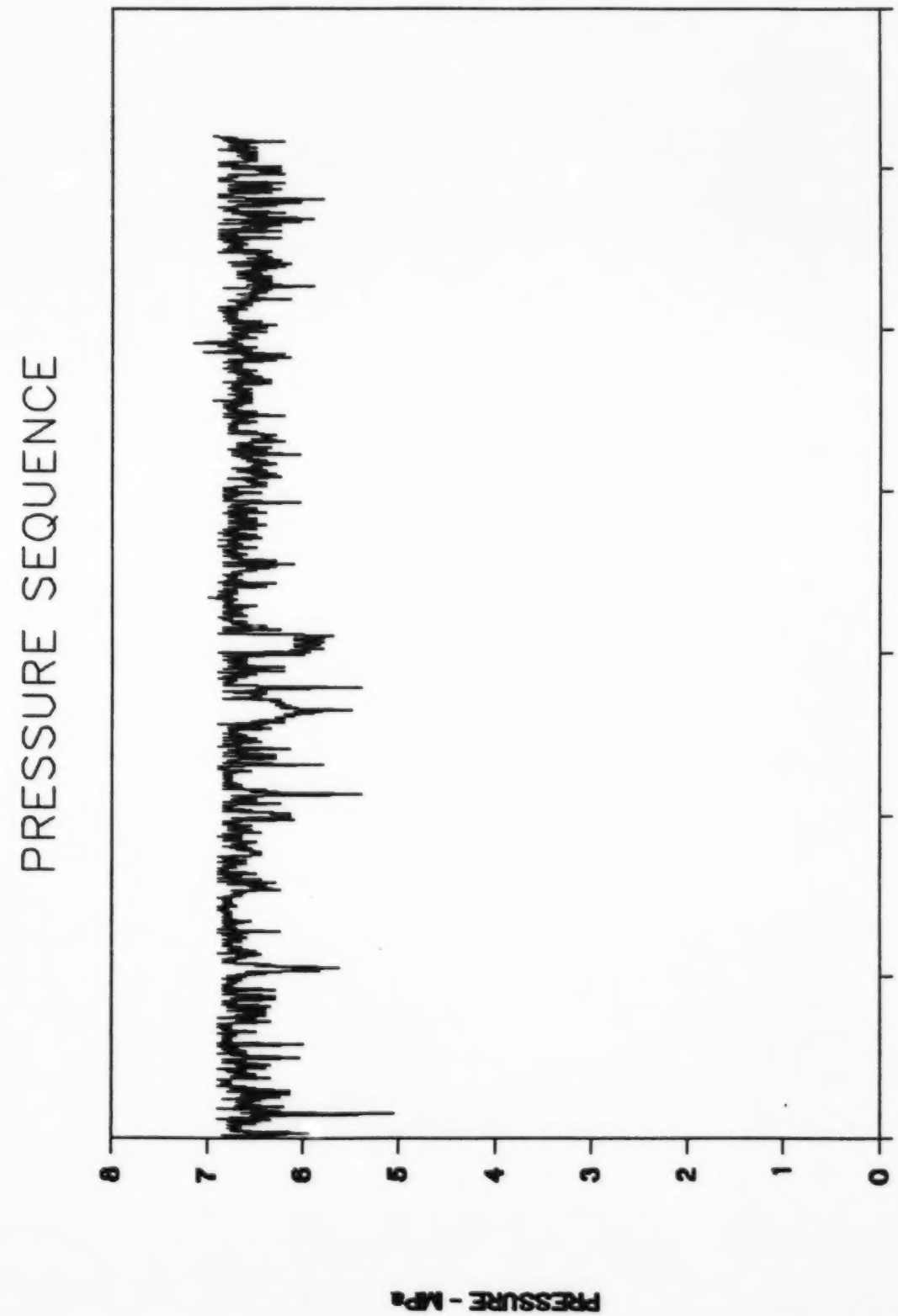
PRESSURE SEQUENCE
PRESSURE - MPa
0
1
2
3
4
5
6
7
8
0
200
400
600
REVERSALS

Fig. 1

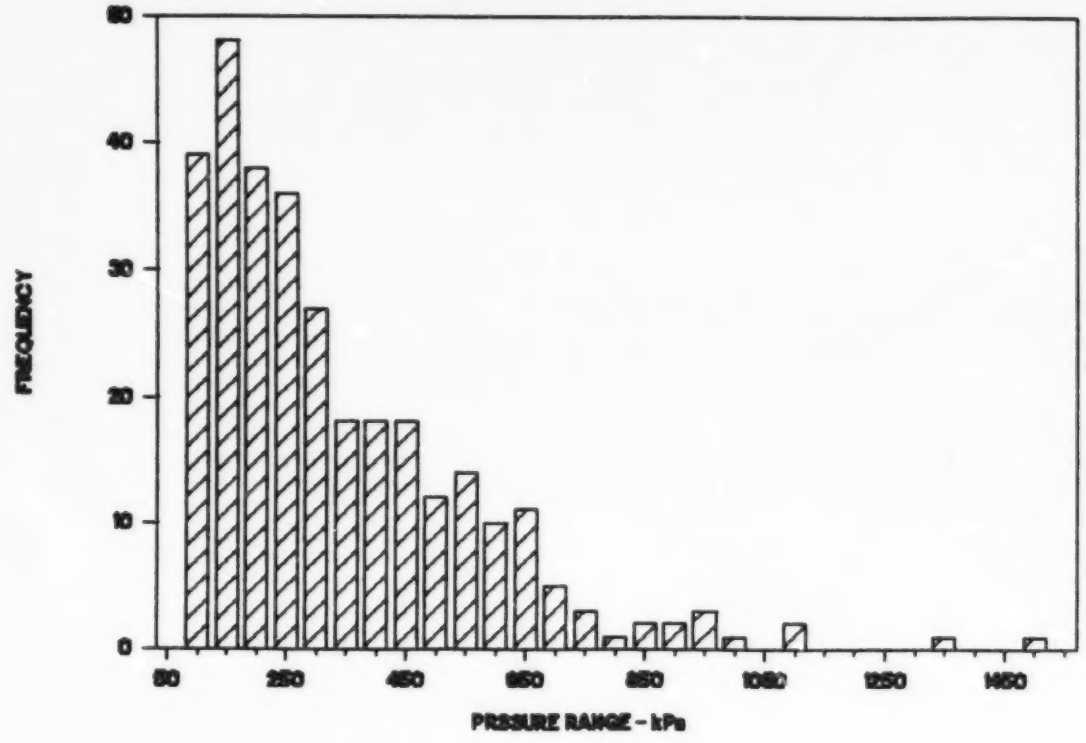
DISTRIBUTION OF RANGES
FREQUENCY
0
10
20
30
40
50
250
450
650
850
1050
1250
1450
PRESSURE RANGE - kPa

Fig. 2a

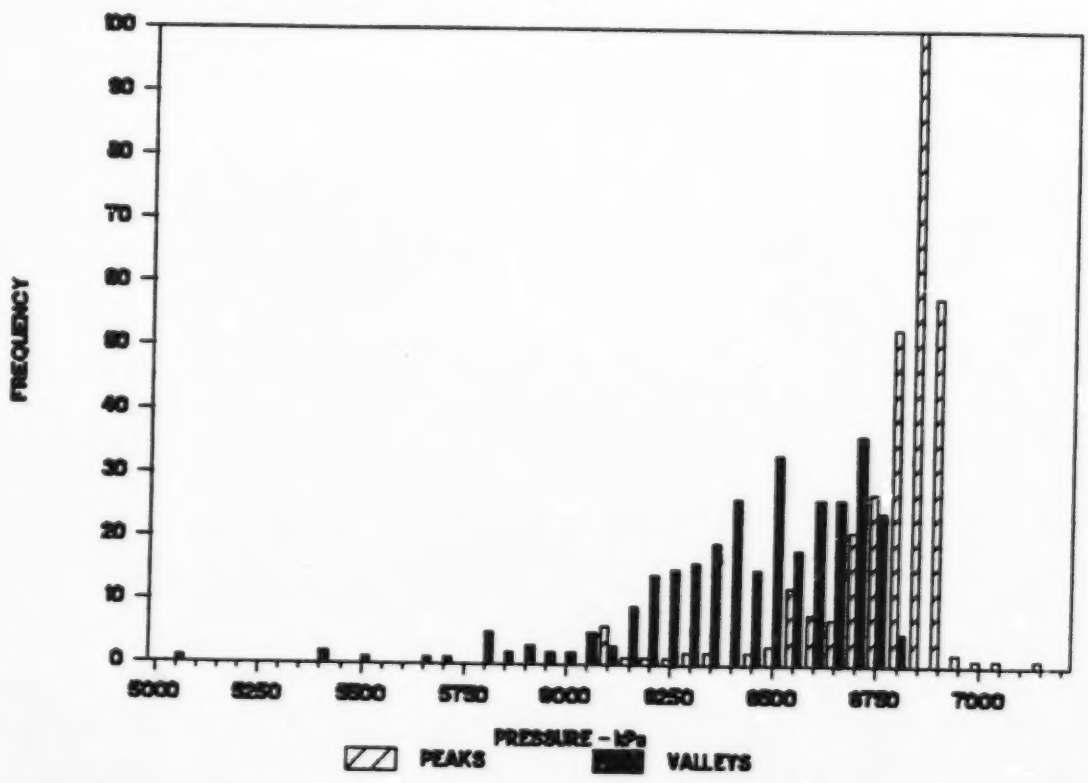
DISTRIBUTION OF PEAKS AND VALLEYS
FREQUENCY
0
10
20
30
40
50
60
70
80
90
100
5000
5250
5500
5750
6000
6250
6500
6750
7000
PRESSURE - kPa
PEAKS
VALLEYS

Fig. 2b

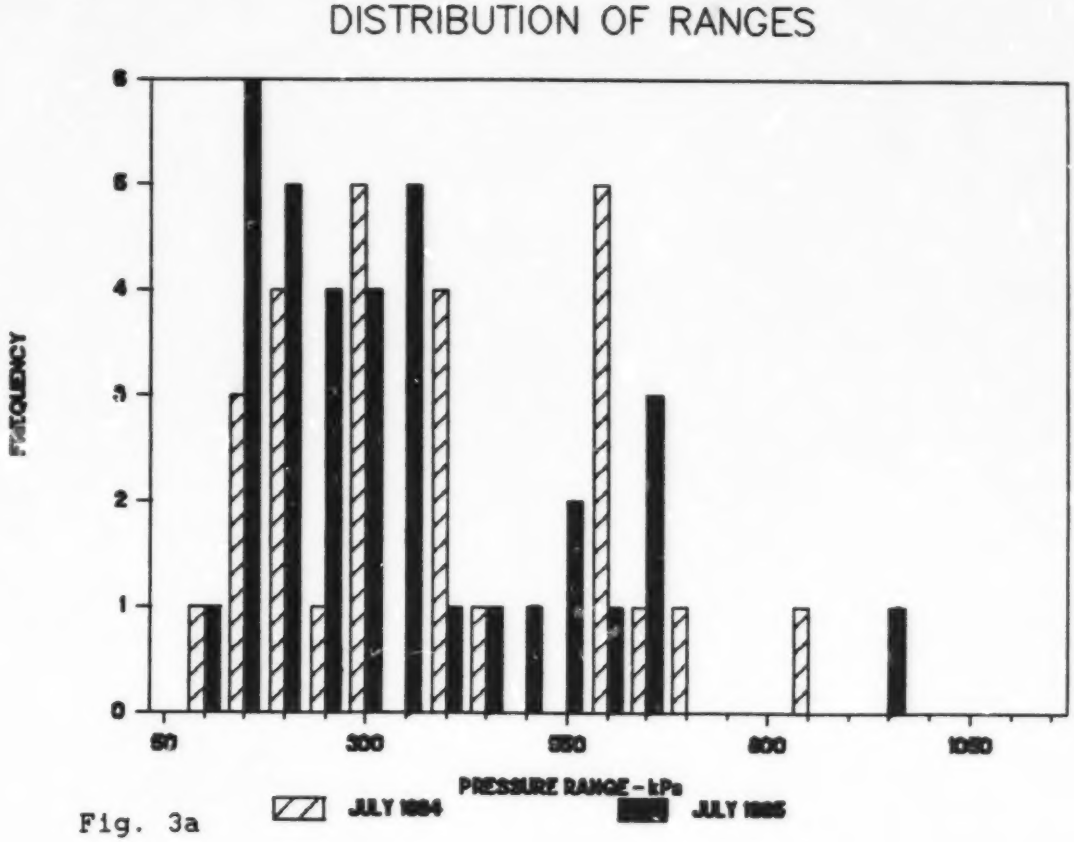
DISTRIBUTION OF RANGES
FREQUENCY
0
1
2
3
4
5
6
300
PRESSURE RANGE - kPa
JULY 1984
JULY 1985

Fig. 3a

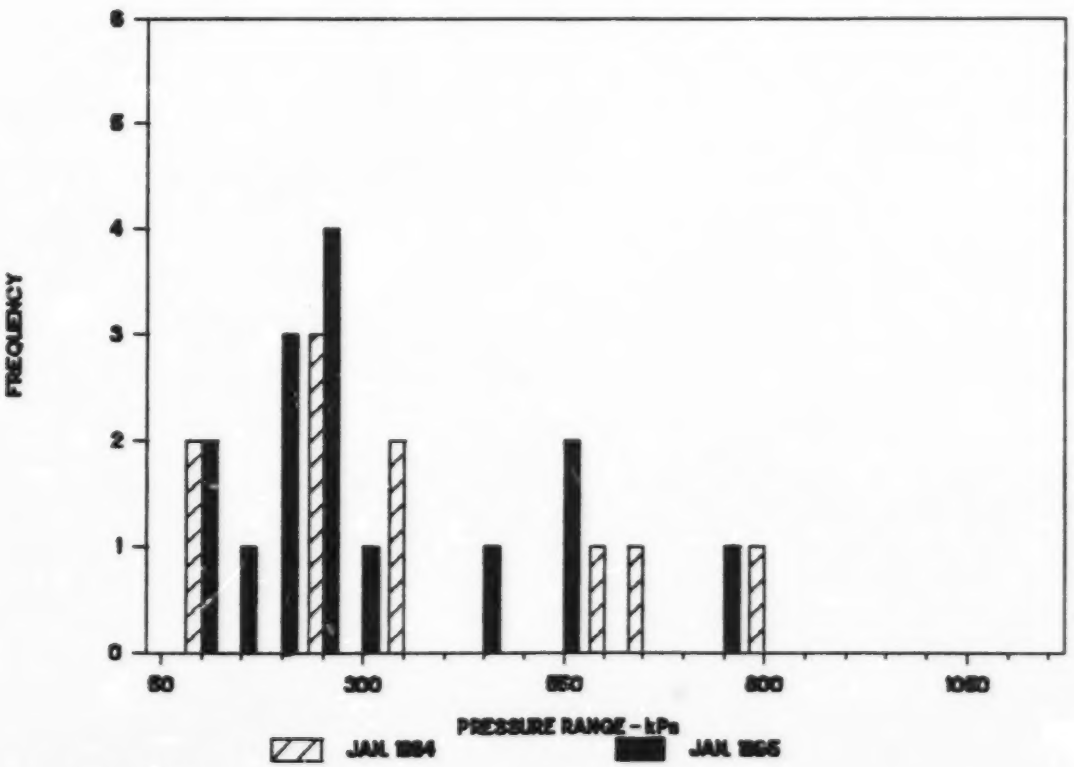
FREQUENCY
0
1
2
3
4
5
6
300
PRESSURE RANGE - kPa
JAN. 1984
JAN. 1985

Fig. 3b